OPEN-FILE REPORT 2000-007

SEISMIC HAZARD EVALUATION OF THE MOORPARK 7.5-MINUTE QUADRANGLE, VENTURA COUNTY, CALIFORNIA

2000

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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CONTENTS

ILLUSTRATIONS

PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
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Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/index.htm).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Moorpark 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Moorpark 7.5-Minute Quadrangle, Ventura County, California

By
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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Moorpark 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within the upper 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Moorpark Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of low-lying shoreline regions, alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Moorpark Quadrangle covers an area of about 62 square miles in southern Ventura County and includes part of the City of Moorpark and the unincorporated rural communities of Bardsdale and Somis. The center of the project area is located approximately 45 miles northwest of the Los Angeles Civic Center and 17 miles east of the Ventura County Civic Center. The Santa Clara River Valley occupies the northwestern corner of the quadrangle. Mountainous terrain of South Mountain and Oak Ridge characterizes the northern and central area. Elevation within the quadrangle ranges from about 250 feet along the Arroyo Las Posas to 2228 feet on Oak Ridge. The steep, highly dissected northern slopes of the Las Posas Hills form the southern boundary of the map area. In the southeast, Little Simi Valley, drained by Arroyo Simi/Arroyo Las Posas, separates the southern flank of Oak Ridge from the Las Posas Hills. The Las Posas upland area, a broad elevated region that slopes gently to the south, separates the South Mountain-Oak Ridge highlands from the Las Posas-Camarillo Hills between Little Simi Valley on the east and the Oxnard Plain on the west. This relatively low-lying area is also referred to as the Las Posas Valley. Numerous north-south-trending drainages cut South Mountain and Oak Ridge creating steep narrow canyons on north-facing slopes and wide flat-bottomed canyons with incised streams on south-facing slopes.

A network of residential streets and ranch and oilfield roads that traverse the area from U.S. Highway 101 and State Highways 118, 23, and 126 provides access within the project area. Current land use includes citrus and avocado orchards, oil-well drilling and production, sand and gravel quarries, decorative-rock quarries, cattle grazing, suburban residential development, and golf courses.

GEOLOGIC CONDITIONS

Surface Geology

A recently compiled Division of Mines and Geology (DMG) geologic map of the Moorpark Quadrangle (Irvine, 1995) was digitized for this project by Southern California Areal Mapping Project (SCAMP) staff. In addition, William Lettis and Associates (1999) provided new Quaternary geologic mapping in digital form for use in this study. This map was merged with the digitized geologic mapping by Irvine (1995) to provide a common geologic map for zoning liquefaction and earthquake-induced landslides. Nomenclature for labeling Quaternary geologic units followed that applied by the Southern California Areal Mapping Project (Morton and Kennedy, 1989). Quaternary geologic mapping of the Moorpark Quadrangle is presented as Plate 1.1.

As illustrated on Plate 1.1, Quaternary sediments mapped in the Moorpark Quadrangle are composed of material deposited in river and stream valleys, canyons, and small mountain valleys. Depositional environments of this type cover about 30 percent of the local terrain. The Quaternary surficial alluvial units are divided into older alluvium (Pleistocene), younger alluvium (latest Pleistocene to Holocene), and modern deposits. They are subdivided further on the basis of their depositional environment and relative age based on geomorphic expression (Table 1.1).

Subsurface Geology and Geotechnical Characteristics

Logs of more than 55 borehole test sites were collected from the City of Moorpark, the County of Ventura, Los Angeles County Public Works, California Department of Transportation (CalTrans), and the Southern California Regional Water Quality Control Board. Locations and geotechnical data from borehole logs were entered into DMG's Geographic Information System (GIS). Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections using data reported on the borehole logs enabled staff to relate soil engineering properties to various depositional units, to correlate soil types from one borehole to another, extrapolate geotechnical data into outlying areas containing similar soils, and to evaluate ground-water conditions.

Quaternary Map Units	Environment of Deposition	Age
Qw, Qw1, Qw2	Wash	Historic time
Qf	Alluvial Fan	Historic time
Qc	Colluvium	Historic – Holocene
Qya1, Qya2, Qya3	Alluvium	Holocene
Qyf1, Qyf2	Alluvial Fan	Holocene
Qoa	Alluvium	Pleistocene

Table 1.1. Quaternary geologic units mapped in the Moorpark Quadrangle.

Borehole log data indicate that alluvial sediments deposited in lowland basins, canyons, and stream valleys throughout most of the Moorpark Quadrangle are generally dominated by fine sand and silt derived mainly from the Pliocene-Pleistocene Saugus Formation (see Section 2 for descriptions of the pre-Quaternary geologic units).

GROUND-WATER CONDITIONS

Liquefaction hazard mapping focuses on areas historically characterized by ground-water depths of 40 feet or less. Accordingly, ground-water conditions were investigated in the Moorpark Quadrangle to evaluate the depth to saturated sediments. Saturated conditions reduce the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). Ground-water depth data were obtained from geotechnical borehole logs and water-well logs. The evaluation was based on first-encountered water levels encountered in the boreholes and selected water wells. The depths to first-encountered water, free of piezometric influences, were plotted onto a map of the project area showing depths to historically shallowest ground water (Plate 1.2). This map was digitized and used for the liquefaction analysis.

Shallow ground-water conditions in the Moorpark Quadrangle occur in and adjacent to the floodplains of the Santa Clara River, Arroyo Las Posas/Arroyo Simi, and their tributaries. Near or at-surface historic water depths are common along the Santa Clara River, whereas depths of 15 to 30 feet characterize the latter. Shallow ground water also is assumed to occur within the canyons that are tributary to the two major stream valleys.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Moorpark Quadrangle, peak accelerations ranging between 0.54 to 0.94 g (Fillmore area near the San Cayetano and Oak Ridge faults) resulting from earthquake magnitudes ranging between 6.7 and 6.9 were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. These properties and conditions are correlated with geologic age and environment of deposition. With increasing age of a deposit, relative density may increase through cementation of the particles or the increase in thickness of the overburden sediments. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silty units of low plasticity are treated as liquefiable in this investigation. Cohesive soils are generally not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in lower liquefaction susceptibility generally result in higher penetration resistances to the soil sampler. Different blow count corrections are used for silty sand and nonplastic silt than for clean sand (Seed and others, 1985). Therefore, blow count or cone penetrometer values are a useful indicator of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (more likely to liquefy). Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. DMG's qualitative susceptible soil inventory is summarized on Table 1.2

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Geologic Map Unit	Sediment Type	Environment of Deposition	Consistency	Susceptible to Liquefaction?*
Qw Qw1, Qw2	Sandy, silty sand	active stream channels	Loose	Yes**
Qf	Silty sand, sand, minor clay	active alluvial fans	Loose	Yes**
Qc	Clay, silt, sand, rock debris	Colluvium, slope wash	Loose	Not Likely
Qyf1-2, Qya1-3	Silty sand, sand, minor clay	young alluvial fans and valley deposits	Loose to moderately dense	Yes**
Qoa	Cobbles, gravel, sand, silt, and clay.	older alluvial fans and valley deposits	Dense to very dense	Not likely

* When saturated.
** Depending on clay content

Table 1.2. General geotechnical characteristics and liquefaction susceptibility of Quaternary sedimentary units.

Of the 55 geotechnical borehole logs reviewed in this study (Plate 1.2), 31 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve-test values or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Moorpark Quadrangle is summarized below.

Areas of Past Liquefaction

No areas of documented historic liquefaction are known in the Moorpark Quadrangle. Areas showing evidence of paleoseismic liquefaction have not been reported.

Artificial Fills

Artificial fill is not mapped at the scale presented for the Moorpark Quadrangle.

Areas with Sufficient Existing Geotechnical Data

Sufficient existing geotechnical data in the alluviated lowland areas of the Moorpark Quadrangle are limited to the vicinities of Moorpark, Bardsdale, and Somis (Plate 1.2) where test drilling for construction and environmental purposes is concentrated. These areas have been zoned for liquefaction hazards where historically saturated, loose sandy sediments exist within 40 feet of the surface.

Areas with Insufficient Existing Geotechnical Data

It was necessary to apply SMGB criteria for zoning areas lacking sufficient geotechnical data to parts of the Santa Clara River valley and the Las Posas Valley, along with stream canyons and the highland alluviated areas situated in the mid region of the quadrangle. Although numerous non-technical water-well descriptions indicate that alluvial deposits within 40 feet of the surface are composed of sand-rich material, the engineering properties of the sediments cannot be adequately evaluated.

ACKNOWLEDGMENTS

The author thanks Christopher Hitchcock of William Lettis and Associates for providing original mapping and discussions of the Quaternary geology of the Moorpark Quadrangle. The author also extends his appreciation to managers and staff of the City of Moorpark, Ventura County Public Works Agency, Ventura County Environmental Health Division, California Department of Transportation (CalTrans), and the Los Angeles Regional Water Quality Control Board for providing geotechnical data that were critical to the successful completion of this study.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Moorpark 7.5-Minute Quadrangle, Ventura County, California

By
Michael A. Silva and Pamela J. Irvine

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Moorpark 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, in loose soils, and on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Moorpark Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Moorpark Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Moorpark Quadrangle covers an area of about 62 square miles in southern Ventura County and includes part of the City of Moorpark and the unincorporated rural communities of Bardsdale and Somis. The center of the project area is located approximately 45 miles northwest of the Los Angeles Civic Center and 20 miles east of Ventura. The Santa Clara River Valley occupies the northwestern corner of the quadrangle. The northern and central area is characterized by the mountainous terrain of South Mountain and Oak Ridge. The steep and highly dissected northern slopes of the Las Posas Hills form the southern boundary of the map area. Little Simi Valley, drained by Arroyo Simi/Arroyo Las Posas, separates the southern flank of Oak Ridge from the Las Posas Hills in the southeast. The Las Posas upland area, a broad elevated region sloping gently to the south, separates the South Mountain-Oak Ridge highlands from the Las Posas-Camarillo Hills between Little Simi Valley on the east and the Oxnard Plain on the west. This area is also referred to as the Las Posas Valley because it is relatively low-lying. Numerous north-south-trending drainages cut South Mountain and Oak Ridge creating steep narrow canyons on north-facing slopes and wide flat-bottomed canyons with incised streams on south-facing slopes.

Access within the project area is provided by a network of residential streets and ranch and oil-field roads that traverse the area from U.S. Highway 101 and State Highways 118, 23, and 126. Current land use includes citrus and avocado orchards, oil-well drilling and production, sand and gravel quarries, decorative rock quarries, cattle grazing, suburban residential developments, and golf courses.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

A recently compiled Division of Mines and Geology (DMG) geologic map of the Moorpark Quadrangle (Irvine, 1995) was digitized for this project by Southern California Areal Mapping Project (SCAMP) staff. Landslide deposits were deleted from the digital map so that the distribution of bedrock formations and the landslide inventory would exist on separate layers for the hazard analysis. DMG staff then merged the bedrock contacts on this map with a digital Quaternary geologic map prepared by William Lettis and Associates (1999). The contacts between bedrock and Quaternary surficial deposits on the merged map were then modified based on air-photo interpretation and field reconnaissance by DMG. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The oldest geologic unit mapped in the Moorpark Quadrangle is the upper Eocene to lower Miocene Sespe Formation (Tsp), which crops out along the eroded axes of anticlines on the northern flanks of South Mountain and Oak Ridge in the north, and along the Las Posas Hills in the south. The Sespe Formation consists of alluvial fan and floodplain deposits of interbedded pebble-cobble conglomerate, massive to thick-bedded sandstone, and thin-bedded siltstone and claystone.

In the northern part of the map area, Sespe Formation is overlain by and interfingers with the upper Oligocene to lower Miocene Vaqueros Formation (Tv), which is composed of transitional and marine sandstone, siltstone, and claystone with local sandy coquina beds. In the Las Posas Hills, Sespe Formation is unconformably overlain by marine sandstones of the middle Miocene Topanga Group (Ttss; undifferentiated), which are interlayered with and intruded by volcanic rocks (basalt flows, breccia, and diabase dikes) of the Conejo Volcanics (Tcv, Tcvi).

The Vaqueros Formation and Topanga Group are overlain by deep-marine strata of the upper Miocene Modelo Formation, which crop out along the crests and southern flanks of South Mountain and Oak Ridge and also occur as isolated outcrops in the Las Posas Hills. Locally, Modelo Formation (Tm) consists of interbedded diatomaceous shale, claystone, mudstone, and siltstone with minor sandstone, limestone, chert, and tuff beds. It also includes an unusual "burnt shale" member (Tmb) containing shale and siltstone altered by subsurface combustion of organic-rich layers to slag and scoriaceous material.

The most widely exposed rock units in the area are the Plio-Pleistocene marine and non-marine Pico and Saugus formations, which crop out on the southern flank of South Mountain-Oak Ridge and on the Las Posas uplands and Las Posas Hills. Locally, the Pico Formation (Tp) consists of marine siltstone and silty shale with minor sandstone and pebbly sandstone. The Saugus Formation overlies and interfingers with the Pico Formation and is composed of interbedded shallow-marine to brackish water sandstone, siltstone, pebble-cobble conglomerate, and coquina beds (TQsm), which grade laterally and vertically into non-marine sandstone, siltstone, and conglomerate (TQs). A local member of the Saugus Formation (TQsv) is exposed in the southeast corner of the map area. It is predominantly a volcanic breccia conglomerate that resembles Conejo Volcanics breccia but is believed to represent remnants of landslide debris shed from Conejo Volcanics into a local trough during Saugus time.

Quaternary surficial deposits cover the floor and margins of the Santa Clara River Valley in the north, Little Simi Valley and Arroyo Las Posas in the south, and extend up into the larger canyons that drain South Mountain and Oak Ridge. Extensive surficial deposits are also present in the Las Posas upland area in the southwest and along a small, structurally controlled basin in the east-central part of the map. These upper Pleistocene to Holocene sediments consist of older and younger alluvial-fan and valley deposits, colluvium, active alluvial fans, and active stream deposits (Qoa, Qyf, Qc, Qoc, Qf, and Qw). Pleistocene- to Holocene-age landslide deposits are widespread throughout the Moorpark Quadrangle, especially in the finer grained Tertiary sedimentary units where bedding planes are inclined in the same direction as the slope (a dip slope). In addition to abundant dip-slope failures, massive slumps are present in the Sespe and Vaqueros formations on anti-dip slopes on the north side of South Mountain and Oak Ridge. Landslide deposits are not shown on the bedrock/Quaternary geologic map, but are included on a separate landslide inventory map (Plate 2.1). A more detailed discussion of the Quaternary surficial deposits in the Moorpark Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked based on their overall shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. For the Moorpark Quadrangle, shear strength data for the rock units identified on the geologic map were obtained from Ventura County and The City of Thousand Oaks (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average ϕ) and lithologic character. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information.

Within the Moorpark Quadrangle, no shear tests were available for Tm, Tmb, TQsm, TQsv, Ttss, Tcv, and Tcvi. Shear test data for Tm from the Thousand Oaks quadrangle was used to assign this unit to existing strength groups. Additional shear tests for Ttcv, and Ts from the Thousand Oaks and Simi Valley West quadrangles were used. Tmb, TQsm, TQsv, Ttss, Tcv and Tcvi were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see “Structural Geology”) and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

The results of the grouping of geologic materials in the Moorpark Quadrangle are in Tables 2.1 and 2.2.

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
MOORPARK QUADRANGLE SHEAR STRENGTH GROUPS							
GROUP 1	Tm(fbc)	28	39	39	500	Tmb(fbc)	39
GROUP 2	TQsm	8	32	32/33	300	TQsv, Ttss	33
	Ttcv	16	32/33			Tcv, Tcvi	
GROUP 3	TQs	70	32/31	30	378	af, Qc, Qf, Qoc, Qw	30
	Qoa	10	31			Qw1, Qw2, Qya1, Qya2	
	Qtp	19	31/29			Qyf1, Qyf2 Qyt1, Qyt2	
	Qal	22	28/27			Tmb(abc), Tsp, Tv	
	Tm(abc)	10	29				
	Ts	18	31/30				
GROUP 4	Qls	3	8/7	8/7	350		8

abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength

Table 2.1. Summary of the Shear Strength Statistics for the Moorpark Quadrangle.

SHEAR STRENGTH GROUPS FOR THE MOORPARK QUADRANGLE

GROUP 1	GROUP 2	GROUP 3	GROUP 4
Tm(fbc)	Ttcv, Tcv	af, Qa, Qc	Qls
Tmb(fbc)	Tcvi, TQsm	Qf, Qoc, Qw	
	TQsv, Ttss	Qw1, Qw2	
		Qya1, Qya2	
		Qyf1, Qyf2	
		Qyt1, Qyt2	
		TQs, Tm(abc)	
		Tmb(abc), Tp	
		Tsp, Tv	

Table 2.2. Summary of the Shear Strength Groups for the Moorpark Quadrangle.

Structural Geology

We used the structural geologic information from Dibblee, (1992) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Moorpark Quadrangle was prepared (Irvine, unpublished) by updating previous work (Irvine, 1995) with field observations and analysis of recent air photos (USGS, 1998). A complete listing of geologic maps and reports that were used to prepare the Irvine (1995) landslide inventory and geologic map of the Moorpark Quadrangle is provided in the references section of that report and is not duplicated here. A list of the air photos used in the preparation of both landslide inventories is included here under Air Photos in References. The 1995 landslide map was scanned and digitized and then modified to reflect the more recent mapping. Then a database of landslide characteristics was prepared containing information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). All landslides on the digital geologic map (Irvine, 1995) were verified or re-mapped during preparation of the inventory map. To keep the landslide inventory of consistent quality, all landslides originally depicted on the digitized geologic map were deleted, and only those included in the final DMG inventory were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Moorpark Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.8 to 7.1
Modal Distance:	2.5 to 5.4 km
PGA:	0.54 to 1.3g

The strong-motion record selected was the Channel 3 (north horizontal component) Pacoima-Kagel Canyon Fire Station recording from the magnitude 6.7 Northridge earthquake (Shakal and others, 1994). This record had a source to recording site distance of 2.6 km and a PGA of 0.44 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.074, 0.13 and 0.21 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Moorpark Quadrangle.

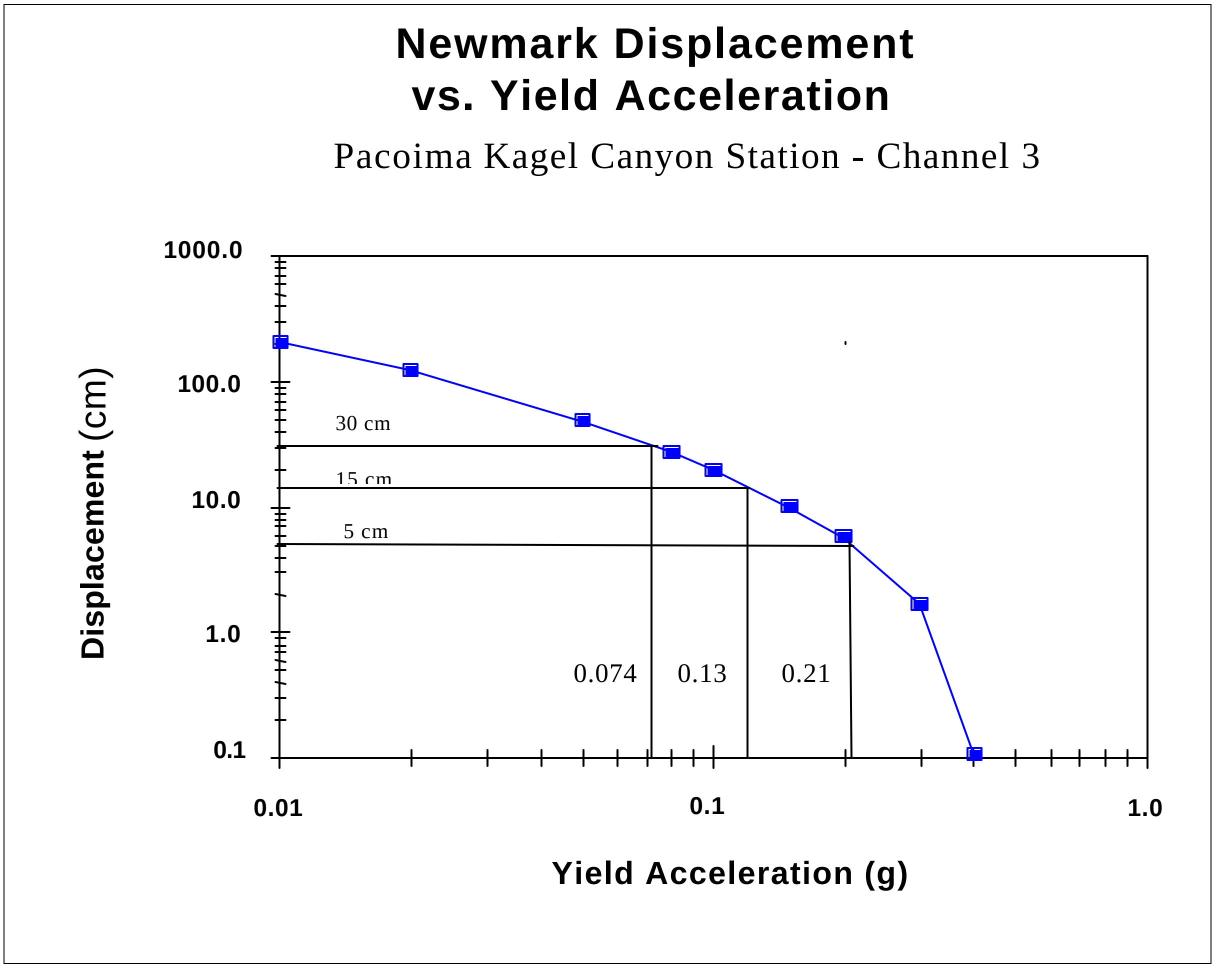

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Pacoima-Kagel Canyon Strong-Motion Record From the 17 January 1994 Northridge, California Earthquake. Record from California Strong Motion Instrumentation Program (CSMIP) Station 24088.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Moorpark Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. A program that adds a pixel to the edges of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

To update the terrain data to reflect areas that have recently undergone large-scale grading, graded areas in the hilly portion of the Moorpark Quadrangle were identified from the NASA 1994 aerial photographs. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and processed by Calgis, Inc. (GeoSAR Consortium, 1995; 1996). The terrain data were also smoothed and filtered prior to analysis. Plate 2.2 shows the area where the topography is updated to 1994 grading conditions.

Slope-gradient and aspect maps were made from the DEMs using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The slope-gradient maps were used first in conjunction with the aspect maps and geologic structural data to identify areas of potential adverse bedding conditions, and then again with the geologic strength map in preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) hazard potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

MOORPARK QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Group	MEAN PHI	SLOPE CATEGORY (% SLOPE) I 0-34	II 34-40	III 40-44	IV 44-50	V 50-55	VI 55-58	XI 58-66	XI 66-72	XI >72
1	39	VL	VL	VL	VL	VL	L	L	M	H
2	33	VL	VL	L	L	M	M	H	H	H
3	30	VL	L	L	M	H	H	H	H	H
4	10	L	H	H	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Moorpark Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (1996). Under those criteria, earthquake-induced landslide zones are areas meeting one or both of the following:

1. Areas identified as having experienced landslide movement in the past (including all mappable landslide deposits and source areas), and, where possible, areas known to have experienced earthquake-induced landsliding during historic earthquakes.

2. Areas where geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

No earthquake-triggered landslides had been identified in the Moorpark Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a number of relatively small, shallow slope failures in and adjacent to the Moorpark Quadrangle (Harp and Jibson, 1995). Soil falls, debris falls, and debris slides occurred in poorly indurated or highly fractured sedimentary rock on steep slopes and along roadcuts. Seismic shaking also enhanced previously existing headscarps of massive bedrock landslides and created additional cracks on steep slopes and ridge tops. Landslides attributed to the Northridge earthquake covered approximately 90 acres of land in the quadrangle, which is 2 percent of the total area covered by the map. Of the area covered by these Northridge earthquake landslides, 86% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 4 is always included in the zone (mapped landslides); strength group 3 above 34%; strength group 2 above 40%; and strength group 1, the strongest rock types, were zoned for slope gradients above 58%. This results in roughly 28% of the land in the quadrangle lying within the hazard zone.

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PACWAS (Pacific Western Aerial Surveys); Flight PW VEN2; May 16, 1978; Frames 49-54, 85-90, 163-167, and 222-228; Color; Vertical; scale 1:24,000.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Ventura County Public Works Agency, Development and Inspection Services	**147**
City of Thousand Oaks, Public Works Department	**49**
Simi Valley West	**8**
Total Tests Used	**204**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Moorpark 7.5-Minute Quadrangle, Ventura County, California

By

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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles.

They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

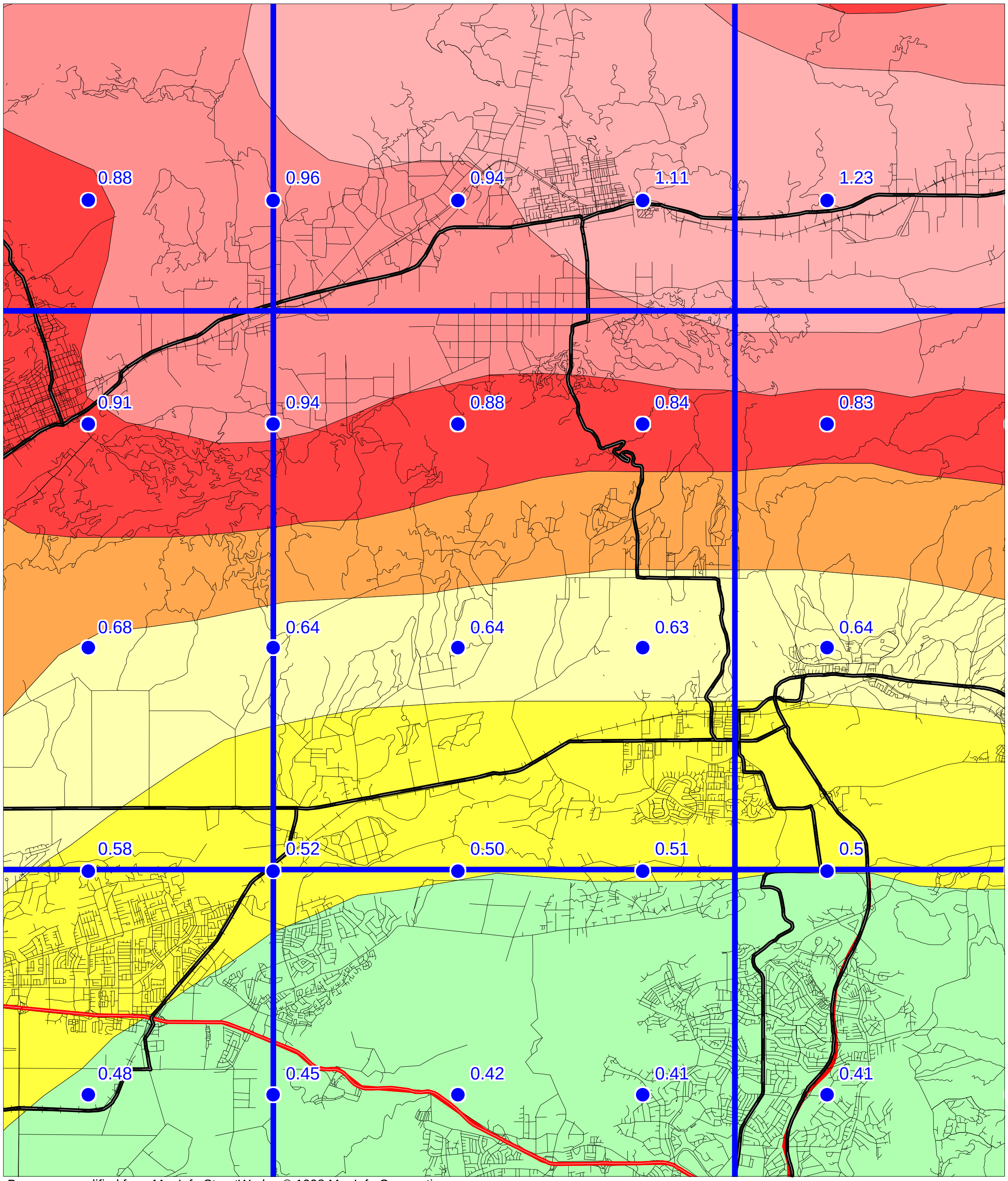
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

MOORPARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5

Kilometers

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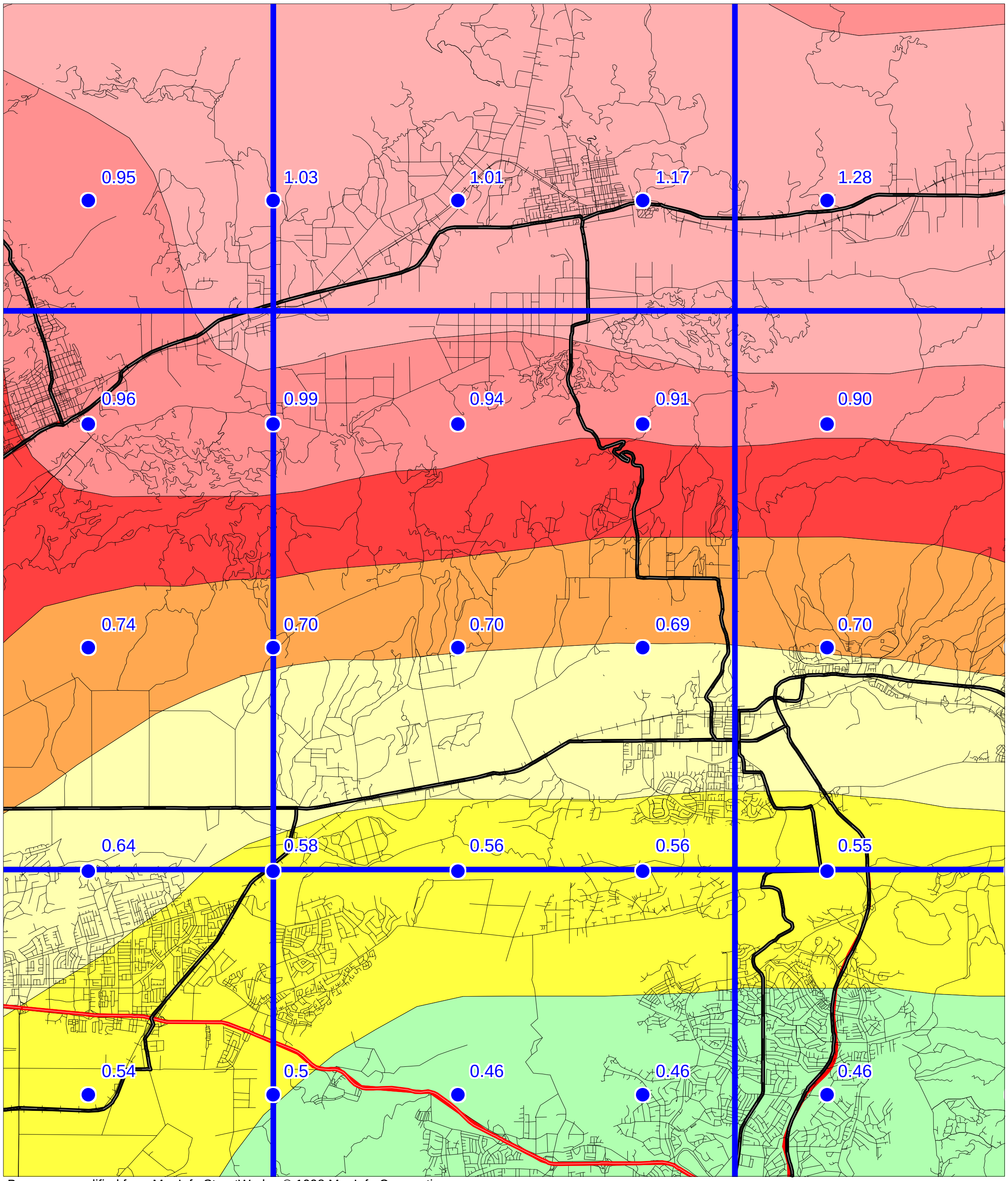
Figure 3.1

MOORPARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
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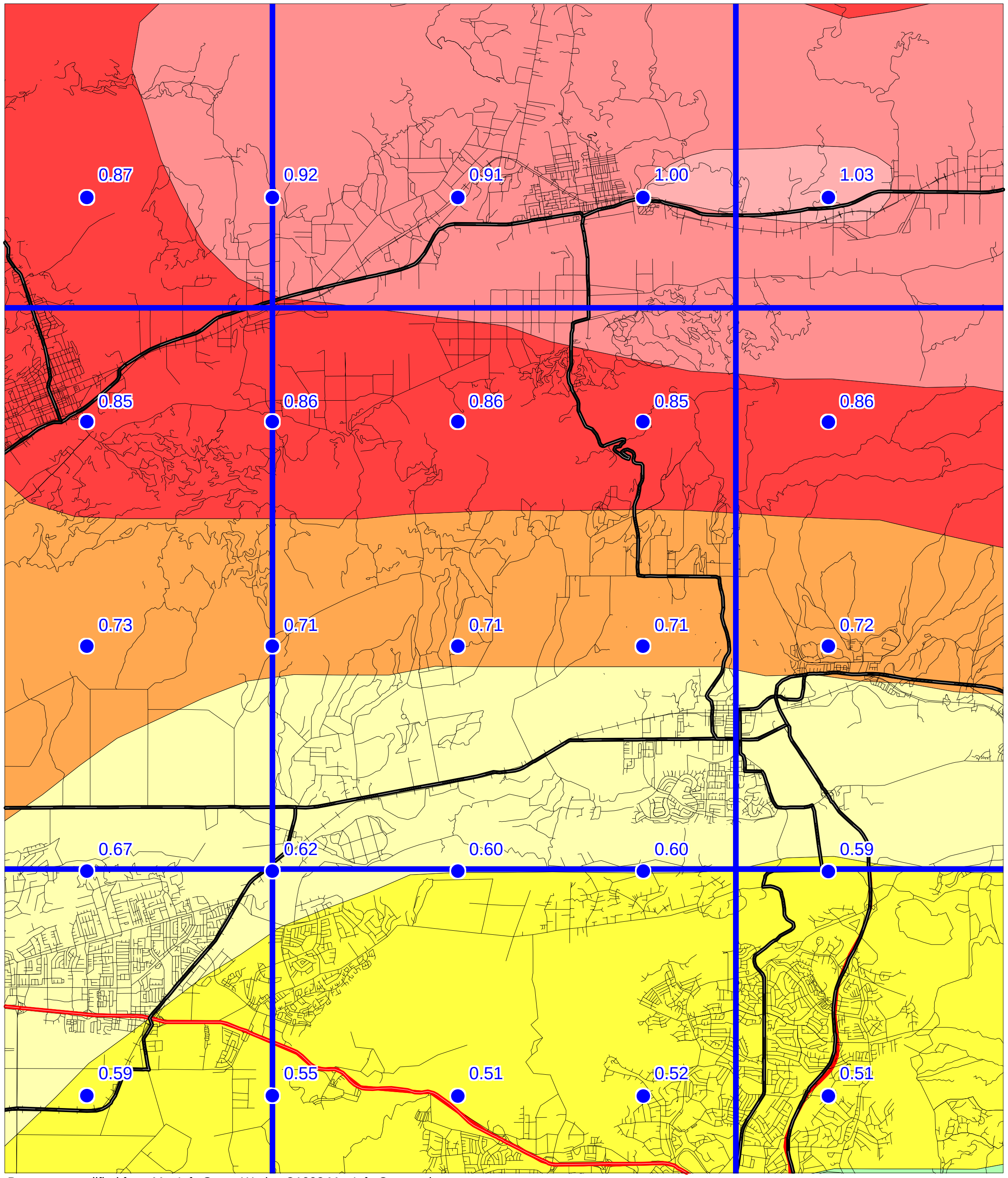
Figure 3.2

MOORPARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

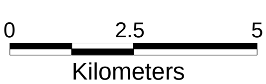


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Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

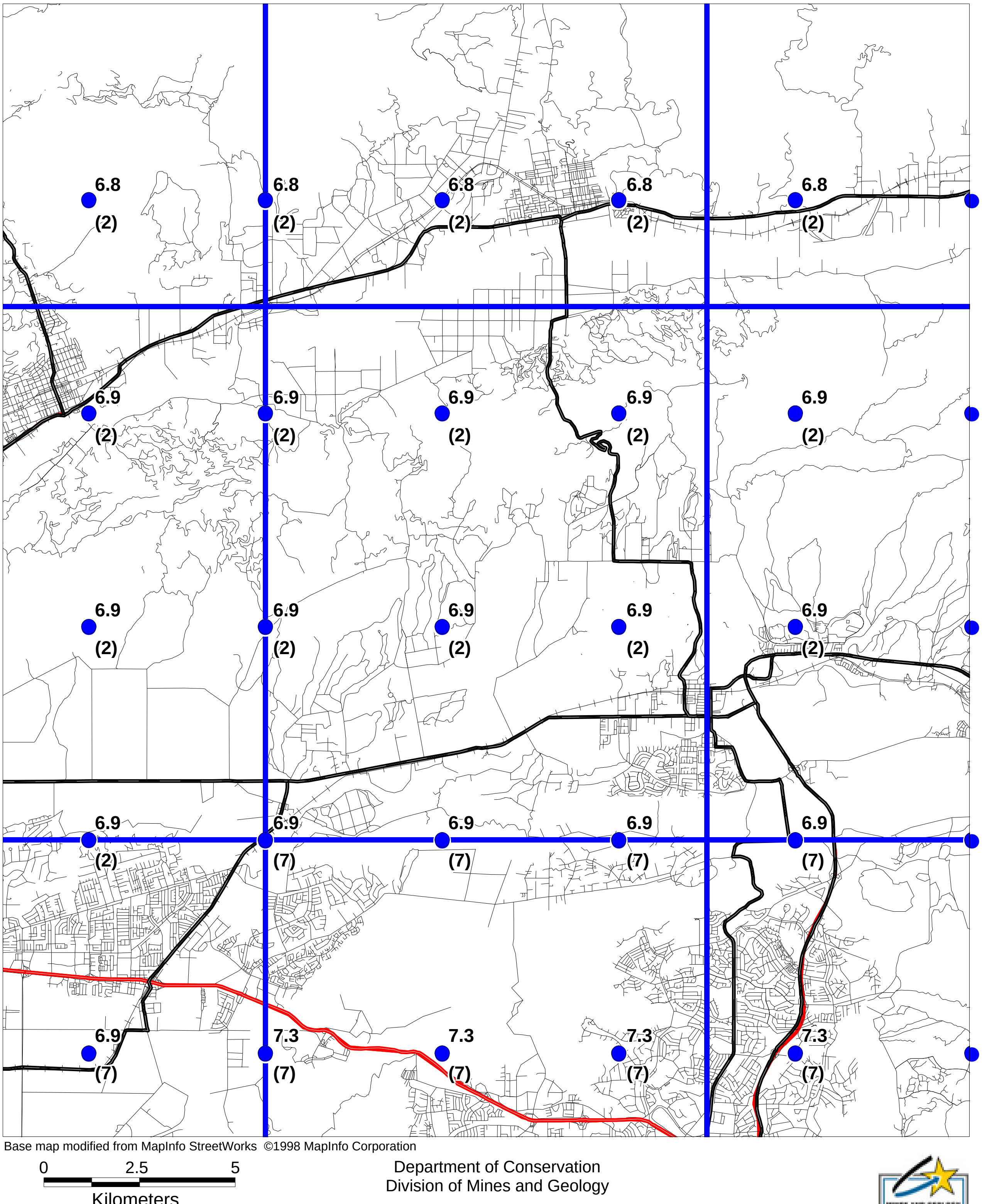
1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation

MOORPARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Department of Conservation
Division of Mines and Geology

Figure 3.4

of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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Base map enlarged from U.S.G.S. 30 x 60–minute series

Geologic mapping modified from William Lettis & Associates, 1999

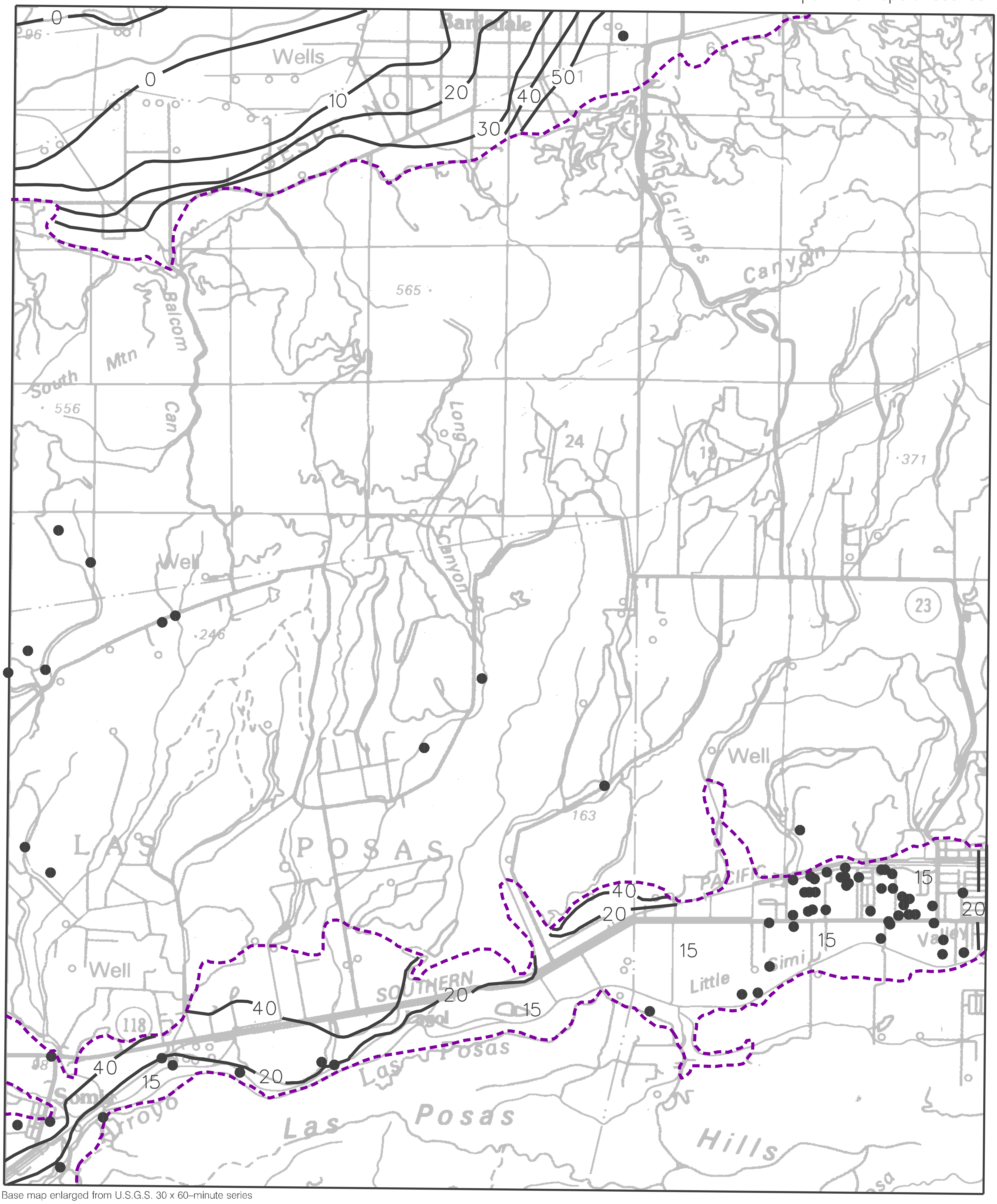
Plate 1.1 Quaternary Geologic Map of the Moorpark Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock.

ONE MILE

Scale



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2 Historically shallow ground–water depths and borehole data points in alluviated valley areas of the Moorpark Quadrangle.

Alluviated Valley

20 Historically shallow ground–water depth contours (in feet)

Borehole Site

15 Historically shallow ground–water depth where same value occurs over a broad area (in feet)

ONE MILE

Scale

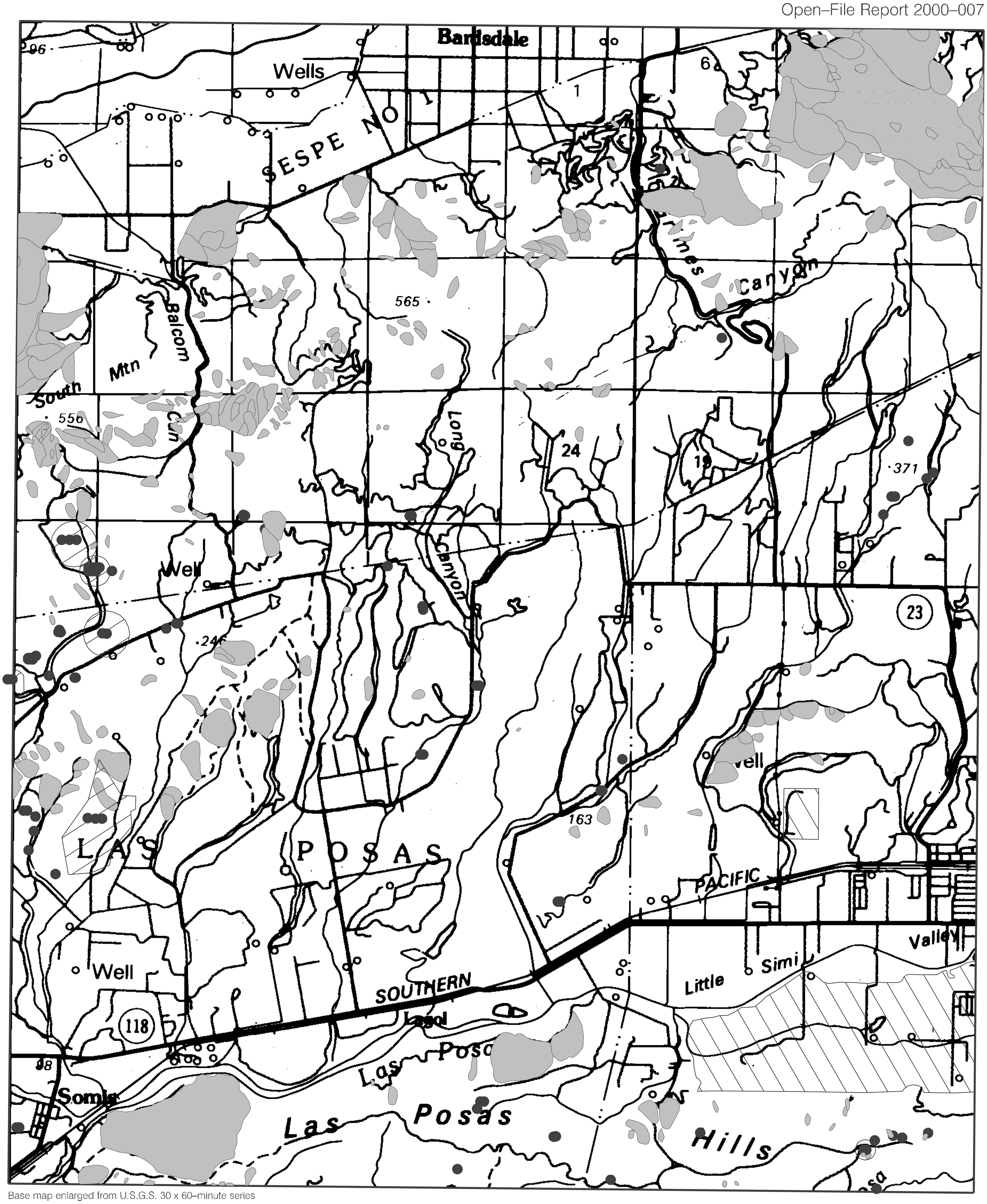


Plate 2.1 Landslide inventory, Shear Test Sample Locations, Areas of Significant Grading, and Tracts with Multiple Borehole Locations, Moorpark Quadrangle.

shear test sample location   landslide   areas of significant grading   tract report with multiple borings

ONE MILE
SCALE